PARASITIC WORMS AND DISEASE
LECTURES ON CERTAIN ASPECTS OF HELMINTHOLOGY

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PARASITIC WORMS & DISEASE:

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PREFACE

The science of helminthology has many votaries in Europe and America. But very little attention has been paid in this country to this important branch of animal biology. It was in an attempt to stimulate the study of this neglected science in India that these lectures were delivered. While the lectures include summaries of recent researches on the subject, advantage has been taken to deal with some of the elementary topics of helminth morphology and life history with a view to meet the needs of the popular reader. As the lectures were illustrated with lantern slides, most of the details of description have been omitted here. At the end of the last lecture is indicated the unlimited scope of work that the subject offers to advanced students who intend to pursue research in this branch of science, which is of such great economic importance to India.

The author is deeply indebted to Professor Birbal Sahni for the encouragement received in the preparation of these lectures for publication. His grateful acknowledgments are also due to Professor R. T. Leiper, F. R. S., of the University of London, for kindly revising these lectures in proof.

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FIRST LECTURE

PARASITIC WORMS AND DISEASE

Animals adapt themselves to different modes of life. Some are fresh-water forms, some are marine and others are terrestrial. They mostly lead an independent existence, ordinarily obtaining their nourishment directly from their environments. But quite a large number of animals live on or within the body of free living organisms which thus form living museums of animal life within. These animals, found on or in the body of other organisms, are known as *parasites* and depend upon the organisms which harbour them for nourishment and protection. These parasites, in many instances, are a source of real danger to their possessors and have exacted a heavy toll from human progress and happiness.

Amongst these parasites are found certain peculiar organisms, with characteristic shapes and movements, which constitute a group of parasitic worms, commonly recognised as "Helminthes." They include the flat leaf-like *flukes*, the long and flat ribbon-like *tapeworms* and the elongated *roundworms.* The study of their structure, habits and life histories forms a distinct branch of Science known as *Helminthology.*

The term 'Helminthes' was used by Hippocrates for some of the worms found parasitic in man and has since been retained merely as a convenient term in medical literature. It has no exact meaning in zoological classification, as these slimy loathsome creatures are so different from each other in their structure, habits, and life-history that they could not be grouped together: they at most signify similarity in environmental condi-

tions within the body of their possessors. In medical terminology, however, Helminthology forms a border-line field in which Zoology, Medicine and Agriculture meet, and like most other border-line sciences, it is inadequately investigated. It is true that some countries, for example England, America and Japan, possess several well-equipped and efficiently-staffed institutions, conducting valuable researches for the benefit and welfare of the human race. But it is a matter for regret that in a large agricultural country like India (excluding Burma) there is at present not a single institution where investigations in the various branches of helminthology can be carried on. It would be no exaggeration to say that in this country helminthology is entirely neglected and receives no encouragement at all. The object of these lectures would be well served if they can create an interest for work on this neglected aspect of economic science in India.

The organisms in or on which these parasites live are termed the *hosts* and there may be one or more hosts for a parasite, according to its occurrence during its migrations in one or more organisms. The host in which the adult parasite is found is the *final* or *definitive* host and the others in which the migratory stages live are termed the *intermediate* hosts or *carriers*.

The universality of the occurrence of helminth parasites can well be judged from a survey of the parasitic worms in the different parts of the body of man and domestic animals alone. Here they are found in almost every part of the body—in the intestine, the liver, lungs, blood vessels, muscles and brain—causing various diseases to the organs in which they occur. Thus, *Oesophagostomes* cause tumours in the intestine of man and domestic animals. The liver-rot, a disease causing heavy loss in meat-producing countries, is due

to the presence of a large distome, *Fasciola hepatica*, in the liver of herbivorous animals, obstructing the biliary passages. A closely allied form, *Fasciolopsis buski*, occurs in the intestine of man in the Oriental countries where Trapa-nuts (*singhârâ*) are used in an uncooked condition.

Although *Fasciola hepatica* is found generally in the herbivorous animals it may be an accidental parasite in the human liver, but the Chinese liver fluke, *Clonorchis sinensis*, causes similar obstructions in the human liver and the presence of *Opisthorchis* gives rise to similar symptoms in dogs and cats.

The peculiar granulations in the human lung, giving it a pseudo-tubercular appearance, were observed by Sir Patrick Manson to be due to the presence of a fluke which was subsequently described by Cobbold as *Paragonimus*. This parasite is fairly common in the Far East and is also found in the lungs of the tiger, cat, fox, wolf, dog, panther and pig.

The presence of flukes in the blood vessels of man was discovered by Bilharz in Egypt. These cause various symptoms associated with urticarial blotches, itching, creeping dermatitis and the passage of blood in the urine. It has been a source of great anxiety and affliction there.

The occurrence of the cysticercus in the muscles of pig and in the brain of man has been observed on many occasions. In the latter case it has often been the cause of insanity.

The peculiarly repulsive disease called ' elephantiasis,' at one time confused with leprosy, was shown to be associated with thread-like worms in the lymphatics.

An interesting hypothesis of worms as a cause of appendicitis has received considerable attention in recent years and on several occasions *Enterobius* and other worms have been recovered, substantiating the statement.

Sir William Osler drew attention to the diagnosis of typhoid fever or ptomaine poisoning and to rheumatism in subacute later stages as a result of *Trichina* worm infections. Owen reported its accidental occurrence in tuberculosis of the lung, and it may be said that it played its part in the formulation of the Mosaic injunction against the use of pork.

The discovery of *Oculotrema hippopotami* from the eye of the hippopotamus and the frequent affections of eye due to ocular filariasis indicate how some of the delicate parts of the body could be seriously affected by the presence of helminthic infections. It would thus appear that the presence of worms in almost every part of the body has been a source of interest and mystery to the naturalist and physician alike.

The number of helminth species described from man is 119, many of which are associated with disease. Of this number many occur also in domestic animals. But the helminth parasites of domestic animals are said to be exclusive and none of them are accidental parasites. Their number is large and additions are being constantly made to it by the discovery of new forms. The horse, for instance, harbours as many as 70 species of helminth parasites, the dog as many as 99, cattle from 96 to 100, the pig 54 and the fowl as many as 93. Although some parasites of domestic animals occur accidentally in man it is strange to note that none of the parasites of the horse are ever found in man in spite of their close association for such a long time.

The damage that these parasites cause to live-stock in India cannot be adequately estimated, as exact data are not available and often their occurrence passes unnoticed. Further, owing to the absence of systematic

work in India, many instances of the death of various animals due to helminthic infections have not been recorded. However, in America, where intensive work of this kind has been carried out, the loss by death due to worm infestation has been estimated and amounts to a very considerable figure. Thus 75% of chicks die of gapes; 80% of sheep die of parasites, and 45% of pigs likewise die of parasitic infections. This, however, does not include the loss that may be due to the damage caused to the leather and hides, nor does it include the diminution of returns from the lowered production of meat, milk, eggs, and horse power. Considering the loss to these products of animal origin it appears that the parasites, particularly the helminths, take a very heavy toll, and in undermining the health of our live-stock constitute a "veritable enemy within." My knowledge of the intensity of helminthic infections at the Lucknow slaughter-houses alone (unpublished results) indicates very heavy infections with tapeworms in every intestine examined. Infections due to nematodes and flukes are equally common. All this indicates a very heavy loss to our live-stock industry and further shows the importance of the study of helminthology in veterinary medicine.

The occurrence of helminth parasites in different parts of the body is also a serious cause of disease in plants. Among the crops affected are cereals, grasses, sugarcane and numerous others. The helminths include both root and shoot parasites. Wheat cockles in the inflorescence is due to the multiplication of eelworms (*Anguillulina*) producing black galls in the wheat grains. These galls occur also in the roots, and sometimes the entire wheat plant shows stunted growth.

'Potato sickness' is due to eelworms and is a very persistent disease, affecting the entire crop. Likewise, clovers are attacked with eelworms and the general

symptoms of the disease are apparent by the stunted growth, and the thickening of leaf and flower-stalks. Even sugarcane is not free from the attack of the eelworms which enter the cortex of the roots; and galls on the roots of the beet are also due to these worms. Naturally the sugar industry is affected in the long run. Other kinds of infections occur in the citrus, banana, strawberry and cocoanut, and thus the ravages and grave potentialities of the occurrence of these parasites amongst our food plants can well be realised. It may, however, be pointed out that these eelworms also invade the plants that decorate our homes and gardens. In chrysanthemums the disease spreads by stages soon after the entry of the parasite (*Pathoaphelanchus*) through the stomata. Narcissus, phlox, violets, ferns, orchids, etc., are also attacked by these parasites entering through stomata or otherwise.

Parasites are thus a source of great trouble to the agriculturists and the horticulturists alike. It may be mentioned here that many of these parasites, found also in the soil, are greatly resistant to adverse conditions, withstanding desiccation for years and playing havoc in the vegetable world as much as the helminths of animals do in the animal world.

The presence of parasites in the body of an organism may induce marked pathogenic changes, as has been pointed out above, in the body of the host by the diseased condition of the organs. Other forms, although apparently harmless, nevertheless exercise their influence in undermining the general health of the host, but in determining this influence the numerical strength of the parasites may be the chief factor. In such cases it is the multiplication of the parasite within the body which is to be feared and is likely to be a serious menace.

Parasites may produce a mechanical effect by blocking the various passages of the body with their accumulations. Sometimes the embryos of the parasite are carried about by the lymph and blood stream all over the body. Young sclerostomes in the horse may bring about the obstruction of the main blood vessels, causing aneurysm.

Examples of gross tissue changes from the helminths are not uncommon. Woodworth found prominent swellings in the frontal bones of a skunk due to the occurrence of nematode worms. The formation of cysts around the parasites is the commonest form of morphological change, as, for example, in *Onchocerca* cysts. Worm nodules in the aorta of the dog have been observed to be due to the presence of *Spirocerca* embryos.

In the supply of nourishment to the parasites the host is often starved, and its presence may thus produce a serious physiological effect on the host. Some times the size of the parasite greatly increases; for instance, the cysticercus in the brain may fill up the brain cavity completely and subsequent growth may press against the nervous tissue so as to bring about a sudden end to the life of the host. Cases of hydatid cysts, as large as a football bladder, have been *reported* from cattle in India. The liver-fluke destroys the tissues of the host and thus prevents the functioning of the liver in the animal.

The guineaworm, which is met with all over India, the Sudan and West Africa in an epidemic form, is one of the many examples of worm disease, and is known since ancient times. The presence of the worms in the body produces toxic effects, as well as local symptoms, *e.g.*, nausea, diarrhœa, giddiness are amongst the usual symptoms produced by these worms on the host.

These are some of the common effects of the parasite on its host. But in order to adapt itself to this peculiar mode of life the parasite must become specialised in several ways. It generally loses its organs of locomotion and of sight. These organs are, however, found during a certain period of the life of the parasite. Thus the "*miracidium*" larva of the liver-fluke has very efficient locomotor organs in the cilia, by which it can actively swim. Eye-spots are also present for the perception of light. Both these structures are lost as soon as the larva enters the body of the snail, but on its emergence from the snail, as a "*cercaria*," it further bears an elongated motile tail for locomotion. This tail is lost as soon as it prepares to enter the body of its host. Thus different modifications of the organs take place by virtue of the adaptability of the parasite for its peculiar mode of life. Since food and warmth are supplied by the host the parasites have not to undergo weary migrations in their search for food and protection. In fact, in some cases reduction goes further, and the parasites lose even their digestive organs, as in the tapeworms, which simply assimilate the already digested food of the host. From the point of view of the parasites, too, there are great risks attached to such a mode of life, for the helminths frequently lose all organs for independent existence. In order to meet this deficiency, and to keep themselves in their accustomed homes, they develop special adhesive organs, like hooks, suckers, etc. In their passage out from the hosts and during their migrations they further risk their life and may even be threatened with extinction. To meet this a prolific development of generative organs and an enormous production of eggs takes place. Rapid multiplication, an efficient mechanism for the maintenance of the race, may take place even during the young stages of the parasite—a feature of exceptional

occurrence in other groups of organisms. Many eggs fall by the way and never develop further, and, amongst those that develop, many fail to reach their destination. Thus, in the course of evolution, the numbers of the offspring produced have become adjusted to meet the death rate, so that under natural conditions the egg or embryo output may be taken as inversely proportional to the chances of reaching the host. If this were not so the parasites would either have died or would have multiplied to such an extent as to exterminate the host.

The question naturally arises as to how the parasites enter the body of the host. In the majority of cases they enter the body with the food. Thus, liver-fluke infection of cattle depends upon the grass on which the young worms are waiting for a chance to attack the host. The human liver-fluke infection is due to eating improperly cooked fish in which the young are encysted. Tapeworm infection likewise depends on eating improperly cooked or raw pork or beef. In some cases the eggs are directly swallowed, and this is due to dirty habits or eating raw vegetables manured with human excreta, thus *Ascaris* infection may be transmitted by salads.

Very often the domestic pets may transfer the infection. The *Echinococcus* parasite of the dog, while it normally migrates through the farm animals, may at times pass into human beings during play with the pets. In man it may be said to be a dangerous disease.

Another mode of infection may be due to the activity of the young parasites themselves. The infective stage of Bilharzia worms actively forces its way through the skin during bathing in canals and ponds which have been subject to contamination.

In the mode of infection by skin-penetration, perhaps, the story of hookworm disease, as revealed by a laboratory accident, is both instructive and romantic. Hookworm (*Ancylostoma duodenale*), as we all know, is an intestinal worm of man in the tropical and sub-tropical countries and is a source of great economic loss. This parasite has been held responsible for the laziness and degeneracy of certain white communities in the tropics, who, descendants from a very noble stock, have been condemned, at places, as a 'disgrace to society.' The eggs of this worm metamorphose in soil and as was discovered by Leuckart in the case of dog hookworm (*A. caninum*) do not require an intermediary. Looss accidentally discovered the mode of hookworm infection in man. In his experiments a drop of water containing the developing embryos of hookworm fell from the dropper on the back of his hand and shortly afterwards he felt an intense itching sensation at the same spot. This led him to conclude that this annoyance was due to something in the water which had been wiped off. Either there was some toxic substance that had been secreted by the young worms or these microscopical embryos had invaded and forced their way through the skin. He, therefore, filtered the culture and applied the clear water to another portion of the skin, but no irritation was caused. On the application of the young embryos intense irritation was again set up, and the mode of entry of the hookworm into the human body through the skin was definitely established. This was further supported by the additional evidence which was manifested by the appearance of the symptoms of hookworm infection and the passage of eggs in the fæces of the experimenter (Looss) himself.

After these personal experiences Looss then carried out exhaustive experiments with dog hookworm,

tracing the course of migration of the larva and showed how, after piercing through the skin, it enters the vascular system, then to the lung and trachea, and ultimately becoming in the gut an adult. Needless to say, the suggestion that this was the route of migration was not at first favourably received, but continued experimental work by other investigators in the field confirmed the romance of the life-history of the hookworm.

It may be mentioned here in passing that in the case of hookworm prevention we have to attack the eggs before they are disseminated and thus depend upon the proper disposal of the nightsoil and also on the destruction of the adults. This work is now being carried out on an intensive scale throughout the world, due particularly to the generosity of Rockefeller. Thus, a beginning has been made and it is hoped that other benefactors would come forward to help in similar fields of work.

SECOND LECTURE

SOME RECENT ADVANCES IN HELMINTHOLOGY

In our last lecture we have shown the intrinsic importance of Helminthology not only to medicine, but also to veterinary and agricultural science. Apart from their purely zoological interest parasitic worms are of importance as agents of disease in animals and plants and thus play an important rôle in the economic welfare of the human race. The work that has been done during the last fifty years or so shows how far the new knowledge acquired by the zoologists in the laboratory and in the field has provided means for the control of the spread of the parasites and gives us hope for the ultimate eradication of the diseases to which these worms give rise.

The parasitic worms and the diseases caused by them were known to the ancients and their references are found in the ancient literature of India, Egypt, and Greece. Thus, *Súsruta* gives a detailed account of as many as twenty different kinds of worms under *Krmi-Roga-Pratisedha*, indicating their origin in fæces, *kapha* (phlegm) and blood, probably as a result of the use of uncongenial and indigestible articles of food. Caraka speaks of the origin of the worms from external filth of the body (*malaja*) and also of the worms which are present in every organism from very birth (*sahaja*). *Dvimukha* of *Súsruta* probably refers to the *Enterobius vermicularis*, which is said to originate from fæces (*purisaja*) producing a pricking pain at the anal passage. Madhava Nidana mentions *Udaravesta* or *Udarada* which Wilson regards as references to tape-worms. *Parisarpa* in the blood evidently refers to the *microfilariae* or some allied worm.

The Ebers Papyrus contains an account of a disease caused by a worm, *Heltu*, which refers to the hookworm

causing profound and intractable anæmia in the tropics. Another disease, *Bilharziasis*, known to the ancient Egyptians and now prevalent throughout Africa, is the one characterised by the passage of blood in the urine. The records of the disease are still available in the bodies of the "mummies," and the manner in which the bathers in the canals sought protection from the parasite is depicted in the temple walls in Egypt. Its reference is also indicated during the Napoleonic invasion of Egypt in 1799—1808.

The guineaworm was mentioned by Plutarch as early as 150 B.C. in his book as little snakes coming out of the leg and arm and retracting when touched. Its reference is also found in the afflictions of the children of Israel during their wanderings from the Red Sea. The indigenous method of its extraction on a piece of stick has been improved upon, and the familiar badge of the Royal Army Medical Corps is thought to indicate this method of treatment of the worm.

Ibn-Sina (Avicenna) knew the peculiarly repulsive disease, elephantiasis, as early as 1037 A.D. (*Vena medinensis*).

The Mosaic injunction against the use of certain meat is probably based on their knowledge of the presence of cystic worms in their flesh and was derived from the older Semitic civilisation.

The origin of these worms was variously discussed on the basis of ill-digested food, presence of bad juices in the organs affected, and from the external filth of the body. In almost every case they were believed to have originated *de novo*. All these theories were, however, discredited by the revelations of the microscope

and it was further demonstrated that they were produced from the eggs discharged to the outside. The eggs develop and undergo changes which explain many important facts regarding the source of their infection. It was then realised that the parasites adapted themselves to this mode of life for better food and protection and probably also for the propagation of the species for a part of their life cycle.

It must be remembered that the helminth parasites rarely infect their hosts directly after they have passed out of the infected person. They must undergo certain changes to produce an infective stage which, as we know, is remarkably different in structure and appearance from the adult worm. It is, therefore, difficult for a physician to determine the control measures without an adequate knowledge of the infective stage. It is true that he may be able to destroy the parasites by medication or, in the case of the infected food-stuffs, etc., by sterilisation. But many helminth parasites of man are also found in the domestic animals who would still act as "reservoir hosts." Thus, for instance, *Paragonimus*, a lung fluke of man, occurs in muskrat, pig, dog, cat and goat; *Ascarids* and *Dipylidium caninum* of dog and cat also occur in children who swallow the embryonated eggs during play. The dwarf tapeworm, *Hymenolepis nana*, occurs in rats and mice, besides man.

Another factor that has been discovered by the application of zoological methods is the knowledge of the infection of parasites by injection into the body by insect bites, as in microfilariae; and, then, there are parasites that penetrate the skin, like hookworm larvae, by their own activities. It is, therefore, of extreme importance to know the sources of danger. The spread of the gospel of sanitation and its refinements will eradicate the

human parasites, but the case of domestic animals is different. In fact, *Taenia solium* is said to have taken the road to extinction when "the mythical Chinaman burned down his house and ate the incinerated pig and pronounced that it was good."

The difficulties of control of the parasites of the domestic animals are due to several factors that may be enumerated thus:—

1. They soil their food with their own fæces.

2. They eat uncooked food, and drink from ponds and streams which they contaminate themselves.

3. Application of sanitation is limited.

All these lead to abundance of parasites and rarity of non-parasitized stock. In fact, the parasites of the stock animals, owing to natural causes, are ever increasing in number. Thus the gradual utilisation of the pastural land for agricultural purposes or for human habitation is constantly reducing the open pastures for grazing purposes, thereby restricting the range area. It is an admitted fact that when there is over-population of the farm animals in a limited area, and suitable control measures are not adopted, the parasites obtain a stronger hold on the host and consequently increase by re-infestation under this restraint.

The modern means of transportation, *e.g.*, wagons, aeroplanes, etc., that carry animals carry also their parasites with them. We know full well the responsibilities of the tourists in the transmission and spread of several diseases. Rabies, which was practically eradicated from England, was reintroduced by a dog brought from France by aeroplane. Thus, in the absence of a

quarantine system for animals, transportation of stock predicates the transportation of the parasites as well. The parasitism of live-stock is, therefore, a real threat.

Again, climatic conditions also affect the parasitism of live-stock. Dry heat and sunshine desiccate the eggs and larvae and thus the pasture would naturally be sterilized, but warmth and moisture would favour the growth of the parasites. In torrential rains the eggs and larvae will be washed away from the pastures and would not get back to the host. Heat without moisture would be deadly for the parasites.

Under the climatic factor it would, perhaps, be worth while to mention the rôle of hibernation in the incidence of parasitism. Very little work has been conducted in this field, and whatever data are available present very contradictory results. Thus, in America, where the work was chiefly done by Duncanson, it was found that in the cold-blooded vertebrates parasitic infections increase up to the time of hibernation, and that the parasites hibernate with the host. On emergence from hibernation the frogs carry the maximum number of parasites which are discharged from the body of the hosts during spawning. The results of my observations at Lucknow, not yet published, during the last two years on frogs and snakes reveal different results. In these animals it was found that the helminths decrease with the onset of hibernation, and during the period of active movements these animals are heavily infected, so much so that during the monsoon months they presented a high percentage of infection. Amongst cattle sheep and goats, however, during the monsoon months the incidence of parasitism decreased, while it increased during the winter months, a period corresponding to the hibernation period of frogs and snakes. In this case it

appears, that the cause of the decrease of parasitism would probably be the excessive rainfall in the United Provinces when the eggs and larvae are washed away by the torrential rains and they do not get an opportunity to develop and reach the final host. Further verification of these results and extended observations in other parts of the country are required.

Lastly, in the case of parasites with intermediate hosts, the occurrence and abundance of them would also be favourable for the growth of the parasites as they would carry the infective stage of the parasite. Zoologists have in recent years studied the life-histories of the helminths and have helped the physicians and the sanitarians to recognise the infective stages of the parasites and have further indicated the conditions under which they would flourish, so that they could eradicate the parasites by the elimination of the conditions required for the completion of the life-history.

In recent years, progress has been made along several different directions—morphology, development, bionomics, classification and relationships. It would be impossible to deal adequately, in this short review, with all the connected problems, but we would first endeavour to discuss some salient features on the migrations of some important helminths of man and domestic animals.

One of the earliest observations on the migrations of helminths was on the nature of the bladder-worms in the organs unconnected with the outside, and which appeared to have strayed from their natural habitat. Owing to the similarity between the hooks on the buds of the cystic worms of pigs and the head of the common tapeworm of man, *Taenia solium*, Küchenmeister traced the connections between them by feeding experiments.

These successful experiments are too fully known to need any further elucidation and the bladder is considered to be a provisional organ for nourishment of the growing tapeworm.

Similarly, the human tapeworm without hooks, which was considered to be an aged form in which the hooks had fallen off with advancing years in the same way as the falling off of teeth and hair in man, was demonstrated by Leuckart to be a distinct species named *Taenia saginata*. From a knowledge of the occurrence of this form in Abyssinia, where the natives rear cattle instead of pigs, Leuckart experimentally showed its cystic stage to occur in cattle. This was received at first with incredulity, but an examination of the cysts from the cattle at the slaughter-houses confirmed the discovery. Thus, a beginning was made in the study of experimental Zoology and it was definitely demonstrated that a second host (intermediary) was necessary for many parasitic worms. It further necessitated a thorough routine meat inspection by the public health authorities in the West.

The complicated life-history of parasitic worms is at times baffling and requires much patience and persistence in its elucidation. This is well-illustrated by the migrations of the broad tapeworm of man (*Diphyllobothrium latum*) which is very common in Switzerland and the countries round the Baltic Sea. Owing to its absence in places where fish does not form an important item of diet, its infective intermediary was found in fish which, as was shown by Braun in 1881, transmitted the parasite to man if eaten in an improperly cooked condition and developed into an adult. But the reverse experiments of feeding eggs to a fish failed to give rise to the young infective larvae. Janicki and Rosen (1917) showed the existence of a primary intermediary

in *Cyclops* (water flea) where the newly hatched embryos pass their early phase till they are swallowed along with the *Cyclops* by the fish. Here they are set free and migrate into the muscles of the fish to attain the infective stage, remaining in it till the fish is eaten by a human host.

Joyeux (1920) confirmed the belief that *Hymenolepis nana* infects without the intervention of an intermediate host, while *Dipylidium caninum* is transmitted by the fleas (*Ctenocephalus canis* or *Pulex irritans*).

The history of Trematode migration dates from 1831, when Mehlis observed a ciliated Infusorian-like body within the eggs of distomes. Siebold (1835) recognised this (*miracidium*) to contain another dissimilar body not different from the "*Kingsyellow worm*" (*Redia*), found earlier by Bojanus in pond-snails, and von Baer (1826) had shown this to give rise to a tailed free swimming organism recognised earlier as an isolated genus of asexual flukes, the *Cercaria*. There was, thus, ample material for the co-ordination of the life-history and thereby linking the observations of earlier workers. Thomas (1883) did this work and further confirmed it by experimental investigations on *Fasciola hepatica*.

In man, allied flukes were discovered in different parts of the body where they were the cause of grave and intractable diseases. The life-history of the lung fluke, *Paragonimus*, of which our knowledge is due mainly to the efforts of the Japanese workers, indicated the presence of a second intermediary in crab to bear the infective stage after the snail. The course of the infective larva in the human body was followed by Yoshida who traced it to penetrate the stomach and

intestinal wall so as to reach the peritoneal cavity by piercing through the diaphragm and pleura and thence to reach the lung by its own migratory efforts.

. The disease that has attracted the most attention during recent years is the "Schistosomiasis" or "Bilharziasis," due to the presence in the blood of the fluke called *Schistosoma haematobium* and other allied species. The chief contribution on the subject is on the mode of its infection in man. It was long held, on the authority of Looss, that this disease was communicable directly from man to man through skin-penetration in the "*miracidial stage*." This view was opposed to all previously acquired ideas of the life-histories of Digenea, but Looss's authority on helminthological matters was unquestionable. Hence all research was directed to the experimental verification of this hypothesis but with no result. Leiper, while investigating the mode of spread of the Trematode infection of man in the Far East, obtained results which discredited the hypothesis of Looss. During the Great European War, when British troops were stationed in Egypt, necessity for preventive measures against the disease arose and the War Office deputed Leiper to proceed to Egypt to investigate the disease and advise preventive measures to be adopted in connection with the concentration of the troops. Thus entrusted with the investigation of a disease that had been prevalent in Egypt since ancient times, Leiper (1915-18) carried on his brilliant researches with creditable success. He found, in tracing out the life-history of this parasite, that the metamorphosis of the *miracidium* follows a history exactly similar to that found in other flukes in a snail intermediary, but differing from them in the fact that the infective stage *i.e.*, the "*Cercaria,*" *does not encyst but bores its way through the skin by its own activity*, thereby omitting

a vehicle-host. Leiper conducted several experiments to test the action of reagents on the infective stage and also the period of its longevity during the free active life. Not only this, he also observed the absence of the operculum in the case of Bilharzia snails, so that long exposure in strong heat and sunshine would easily kill them. These facts, when considered along with the network of irrigation channels and drains which serve as suitable breeding places for the snails, led Leiper to draw conclusions of immense importance for the control of this serious disease. Although I am tempted to enter into a detailed discussion on the subject, time allows me only to sum up the most important conclusions of Leiper. They are :—

1. Transient collections of water are quite safe after recent contamination.

2. All permanent collections of water in the rivers, canals, marshes, etc., are potentially dangerous, depending upon the presence of the intermediate host.

3. The removal of the infected persons would have no effect in reducing the infection, as they do not *re-infect* or spread the disease directly to others.

4. Infection actually takes place through the skin, and is acquired from unfiltered water.

5. Eradication can be effected by destroying the molluscan intermediaries. This could be effected only by seeking assistance of the Irrigation Department which controls the canal system of Egypt, so

that by a periodical control of the flow of water in the canals, the snails (which are non-operculated) would be destroyed by the excessive heat of the bright Egyptian sun and thereby destroy the infective stage.

6. The infective stage *i.e.*, the *cercaria*, has a survival period that does not exceed 48 hours outside the body of the host.

In view of these remarkable results of the utmost importance in the control of this disease, Leiper advises a constructive administrative policy thus. "If a campaign against *Bilharziasis* were commenced on the lines proposed it is evident that the whole scheme should be under the charge of a "medical Zoologist" who should be attached, not solely to the *Public Health* service as in *Ancylostoma* campaigns, but also to the *Department of Irrigation*."

Thus, according to Leiper, full control can be brought to bear upon the *Bilharzia*-carrying molluscs in their eradication from lands heavily infected. I would further add (with special reference to India) that in the case of the helminthiasis of domesticated animals a Zoologist trained in helminthology would be a desirable addition to the Veterinary Department.

Nematodes form by far the greater proportion of the Entozoa of man and animals and have very different modes of migration. The infection of hookworm has already been dealt with as occurring through skin-penetration. It may be mentioned here that the infective stage forms, by ecdysis, a resistant skin that can keep the larvae alive for months without food. In such cases, it would appear that control could only be

effective if the eggs are attacked before they are disseminated. In other words, eradication depends, as already mentioned, upon the proper disposal of the night-soil and upon the destruction of the adults within the body of the host.

The *Trichinella* worm develops in the pig with the infective stage encysted in the muscles, and is usually destroyed in cooking. But the most interesting part disclosed in this connection is that the faeces of swine infected with *Trichinella* are infective to other animals also and this introduces an anomaly in the life-history of the parasite.

The significance of the mosquito in the transmission of different kinds of Filarial infections in man and animals deserves special mention. The young embryos are sucked by mosquitoes where they develop further to return again to the human host by the bite of these insects. *Loa loa* is transmitted by Tabanid flies and *Spiroptera* and *Gongylonema* are transmitted to sheep and cattle by dung beetles.

The life-history of *Habronema muscae* of the horse has been brought to light in recent years and shows the rôle of the house-fly in the transmission of this disease. The eggs or larvae are ingested by the larvae of the house-fly from horse manure. During the metamorphosis of the house-fly, the larval worms find their way into malpighian tubules and thence in the adult fly migrate into the proboscis. The fly, by the application of its proboscis, transmits the larvae to the open sores, lips and conjunctivae of the horse, where they migrate through the body and reach the intestine to become adults.

Many roundworms lay their eggs in soil which after a necessary period of delay enter the human body by

accidental contamination of food. The case of *Ascaris* deserves consideration, as our text-books on Zoology are hopelessly silent on this topic. It would be interesting to mention in this connection that the discovery of this life-history was first made by Stewart who thoroughly investigated and definitely demonstrated that the eggs enter the human body through accidental contamination and pursue a course somewhat similar to that followed by the hookworm larva. The *Ascaris* larvae, on being released by the action of the digestive juices, undergo a long pilgrimage by piercing through the gut wall. They pass to the blood stream, liver and lungs. Here they enter the air sacs, causing haemorrhages as they leave the capillaries and pass up the bronchi, causing the usual symptoms of pneumonia and bronchitis, and, then, through the trachea into the mouth and back again to the intestine where they attain the adult form.

We may end this account with a description of the migration of the guineaworm, *Dracunculus medinensis*, as it presents some interesting facts. The adults live in the connective tissue under the skin and discharge an irritating fluid which, on examination, is seen to contain innumerable active young embryos. These embryos remarkably resemble those of a blood-sucking worm, *Cucullanus elegans*, of perch. Leuckart, on finding this likeness in the embryonic condition, considered the peculiarity to be a special adaptation to assist in attacking some intermediary. Thereupon, he showed the larvae of *Cucullanus* to invade the bodies of the *cyclops* where they metamorphose, and further concluded that the guineaworm would also follow a similar course. Fedschenks, while visiting Persia, substantiated Leuckart's view by testing the hypothesis. It was found that the young worms entered a *cyclops* and metamorphosed in its body. Leiper, however, showed that

after completing this metamorphosis the larvae encyst and when monkeys were fed with these infected *cyclops*, the larvae were released from the cysts by the action of the gastric juice and made their way into the connective tissues, developing into full grown adults after several months. These facts provide a simple and efficacious method of avoiding this disease by the use of strained water freed from cyclops.

Treatment of diseases due to parasitic worms by the use of anthelmintics has come into prominence in recent years. Anthelmintics are drugs which remove worms from the body of the host, chiefly from the digestive tract, and their choice depends upon the habitat as much as the habits of the worm. The most extensive work on the subject is that of Hall who has tested the value of various anthelmintics and has further shown their specific efficacies for different kinds of worm infections in domestic animals. The various drugs commonly used are carbon bisulphide, carbon tetrachloride, tetrachlorethylene, arecoline hydrobromide, oil of chenopodium, thymol, male fern, kamala and chloroform, each having specific effect in the removal of the specific worm. Hall (1932) gives an excellent survey of these anthelmintics that have been successfully used for the treatment of different worms found in various localities in the body of an animal. Thus, oil of chenopodium appears to be very effective for nematode worms, while carbon tetrachloride appears to be effective for flukes and tapeworms. Purgatives are essential for the removal of the after-effects of the drugs whose use must always be controlled under the directions of a competent physician, as they are of the nature of poisons.

THIRD LECTURE

SOME RECENT ADVANCES IN HELMINTHOLOGY (*continued.*)

We have seen how intensive research, carried on in the western countries during recent years, has yielded results to ensure proper control and subsequent eradication of the helminthic diseases. In this connection we have also indicated the help that the zoologist, in the laboratory and in the field, gave to the physician, the veterinarian, the sanitarian and the agriculturist. The factors concerning the helminth transmission may be summed up thus :—

1. The parasitic worms do not ordinarily multiply within the host into a new generation of adults but the eggs must first leave the host which harbours the parents.
2. The eggs or embryos are not infective to the host at the moment of leaving the body. A period of delay is essential for the production of the 'infective stage,' and during this period asexual multiplication of embryos may result.
3. The environmental conditions, like temperature, moisture and water, required for the developmental changes outside the body are varied in different forms. Some may require an intermediate host and others may even need a second intermediary for encystment.
4. The entry of the infective stage may take place through contamination of food, during play or through active penetration of skin.
5. After the entry of the infective stage into the body of the host, the embryo may undertake

an extensive pilgrimage through blood, tissues or serous spaces and may cause serious damage to the parts visited.

6. The 'reservoir hosts' play an important rôle in the spread of helminthic infections.

7. The control of the infections can be brought about by breaking the life cycle thus :—

   (*a*) Medication by means of anthelmintics or therapeutic agents.

   (*b*) Prevention of the entry of the infective stage by any or all of the following methods :—

      (i) Avoid exposure to infective soil. Use of boots and shoes recommended.
      (ii) Avoid open air bathing in canals and ponds liable to contamination.
      (iii) Avoid use of unfiltered water for domestic purposes.
      (iv) Avoid use of uncooked foods: fish, meat, salads, etc.
      (v) Avoid overstocking.
      (vi) Avoid permanent pastures.

   (*c*) Destruction of intermediaries by

      (i) Use of chemicals, like copper sulphate.
      (ii) Introduction of ducks.
      (iii) Sudden exposure to dryness.
      (iv) Application of anti-mosquito measures, fly and beetle control.

   (*d*) Destruction of reservoir hosts.

   (*e*) Proper disposal of manure.

   (*f*) Quarantine introduction, and clean stables.

We will now consider the advances made in the fields of morphology and systematic helminthology, in which a very considerable amount of work has accumulated in recent years, and has been of the greatest value as a basis for work in other fields.

As one result of this recent work, the nomenclature of the helminth parasites has undergone a good deal of revision. This has not been, however, an unmixed advantage because it has thrown many of our standard works on zoology out of date in this respect. University teachers and others interested in the subject, who are not directly in touch with the recent developments, are thus placed under an inevitable handicap. While it is true that the specialised nomenclature must take years before it is generally adopted, the helminthologist cannot help deploring the fact that even the standard works on zoology, like Parker and Haswell (1930) and Sedgwick (1927) still continue to employ antiquated names which are inconsistent with the recent developments. Thus, tapeworms are referred to as species of *Taenia* in a large majority of cases. *T. echinococcus* is used for *Echinococcus granulosus*, *T. cucumaria* for *Dipylidium caninum*, *T. coenurus* for *Multiceps multiceps*.

The common pinworm of man has been referred to as *Oxyuris vermicularis*, though this term has long been discarded in favour of its correct name, *Enterobius vermicularis*. Amongst other examples of the defects in nomenclature mention must be made of *Filaria* for *Wuchereria*, *Dochmius* and *Uncinaria* for *Ancylostoma*, and *Rhabdonema* for *Rhabditis*. It is, therefore, desirable that such defects in nomenclature be now corrected.

The account of the life-history of the common *Ascaris* also needs correction in the light of recent and accepted

views. This has already been described in an earlier lecture.

The classification of *Acanthocephala* has been the subject of great controversy and appears to have been kept in the background in all the standard works in English. Extensive work has been carried out on this group in recent years and Porta, Luehe, Van Cleave, Travassos and Southwell are amongst the chief workers on the group. The earlier classifications on the subject fall under two main heads—those that base their divisions on the nature of the nuclei in the hypoderm and lemnisci and those that have devised the system on the nature and character of the prostate glands. Both these systems have been criticised by Southwell and Macfie (1925) as being unsatisfactory in so far as they are arbitrary and unnatural. These authors, however, did not devise any system but proposed a tentative classification taking the character of the prostate glands which they in their own words declared thus: "No reliance can be placed on the appearance of the prostatic glands of young worms. In mature worms it is frequently extremely difficult to determine their number, but as some authors attach great importance to it, we have been unable to avoid employing it as a diagnostic character (see Echinorhynchidae). Moreover, *our experience has convinced us that the shape and arrangement of the prostatic glands are by no means constant, and as diagnost c characters must not be pressed too far*, only differences of considerable degree being significant." (*Ann. Trop. Med. and Parasit.*, Vol. XIX, p. 142, 1925). While fully subscribing to the views of these distinguished workers, I suggested (*vide* Thapar 1927 *Journal of Helminthology*, Vol. V), a classification of the group, based upon the characters of the proboscis hooks and body spines. It was hoped that this would serve as a workable basis

upon which progress could be made in future years. Van Cleave (1928) though laying stress on his system on the character of the nuclei in the subcuticula, erected two new families, Pallisentidae and Hebosomidae, on characters similar to those indicated by me in my system. The discovery of *Farzandia* (Thapar, 1930a) further confirmed the view about the classification of this group. Meyer, later, considered the arrangement of hooks on the proboscis to be of greater importance and it appears that the value of the characters of hooks is being recognised in the classification of this interesting group of worms.

Much work has been done on the Nematode worms. Railliet and Henry in France have done considerable work on the Strongyles and have given an outline classification as well. Ransom gave a fuller account of the nematodes of the Ruminants. Leiper (1911) successfully demonstrated the nature of "*Onchocerciasis*" or worm nodules in cattle to be due to the nematode of the Filaria Family, *Onchocerca gibsoni*. This disease caused much alarm and called forth a special inquiry by the Government Board but was demonstrated by Leiper to be harmless to man. Grouse disease was demonstrated to be due to a strongyle, *Trichostrongylus pergracilis*, and the anatomy and life-history of this worm was carefully studied by Shipley and Leiper. Oxyurid worms of reptiles formed a subject of extensive study by the author (1925c) when, besides describing the morphology of a few new forms including two new genera, *Alaeuris* and *Veversia*, an account of the genital organs of these interesting worms was given. The presence of spines in the posterior pharyngeal bulb of *Tachygonetria microstoma* was also demonstrated, as also the presence of cilia guarding the excretory pore in *Pharyngodon sp.* These cilia in *Pharyngodon sp.* are fairly stiff and bear basal granules. It is significant to show that the absence

of cilia in a nematode, as held by Shipley, cannot now be correlated with the tendency to form a thick cuticle. In the same communication (Thapar, 1925c), it was further shown that the Oxyurids are not primitive as is believed by Seurat and others but that they form a group of highly specialised nematodes which have attained their simplicity through degeneration. This simplicity is thus only a secondary modification in the group. The evolution of vivipary from ovipary amongst the Oxyurids was also suggested. In the genus *Labiduris* the presence of three distinct bulbs preceded by a vestibulum was shown to be a prominent character in which the genus was unique amongst the Nematoda. So far the single-bulbed and double-bulbed œsophagus were recognised in importance as a family character, and it was now shown (Thapar, 1925c), that a three-bulbed œsophagus appears to be equally prominent and a new family Labiduridae was erected. The presence of rose-thorn-shaped spines in the œsophagus of a new genus *Echinopharynx* Thapar (1925a) was demonstrated earlier in the year. This genus belongs to the Strongylidae and was further peculiar in the fact that, like certain *Ascaridae*, it possessed intestinal diverticula In both these characters—spines in œsophagus and intestinal diverticula—the genus *Echinopharynx* was unique amongst the Strongylidae, sharing, however, the character of spines in œsophagus with another Strongylid genus, *Sauricola*. In a later communication (Thapar, 1927) I demonstrated important differences between *Echinopharynx* and *Sauricola*. In connection with the studies on the genus *Kiluluma*, (Thapar 1924 and 1925b), accounts of the morphology of ten new species of the genus were given and certain morphological points were clearly elucidated. These concern the genital organs of the genus in question. Goodey (1924) demonstrated in the genus *Oesophagostomum* the relation

between the length of the vagina and the spicules, and found that they correspond to each other in length. He, therefore, indicated that this would be the general rule in the Strongylids, but my observations on *Kiluluma* species modifies the rule in the following terms :—

"The length of the spicule *ordinarily corresponds* to the length of the vagina and where this relation does not hold, it will be found that the length of the spicules *varies* with the total length of the vagina and its horn taken together." This relation is of great importance in the isolation of species from each other.

Major work on the Cestodes has been done by Fuhrmann whose numerous contributions have considerably added to our knowledge of the group. This has been extended further by the brilliant researches of Ransom in America and Joyeux and Baer in France and Switzerland. Cameron extended our knowledge of the *Mesocestoides*, a group of tapeworms of great economic importance. The question of the orientation of Cestode *strobila* has attracted considerable attention and from the study of the nervous system it has been finally settled that the scolex of the tapeworm is really the posterior end. Gough (1911) discovered a group of cestodes, *Avitellininae*, having no yolk glands at all.

The question of the homology of Laurer's canal in the Trematodes and Cestodes has been raised and variously interpreted by several authors. Goto (1894) made extensive references to this question in his work on the Ectoparasitic Trematodes of Japan and traced the origin of the trematodes and cestodes from a form which, adopting the terminology applicable to the Monogenea, possessed paired vaginae, the uterus and another duct, the homologue of the genito-intestinal canal. In Digenea, it is regarded as the homologue of the functional

uterus of the Cestodes, but Odhner considers it to correspond with the cestode vagina. In Monogenea, where it was considered to represent the gastro-intestinal canal, he (Odhner) regards it as a structure *sui generis*. In some Monogenea, however, the functional vagina is undoubtedly a homologue of Laurer's canal, and in others it is entirely absent.

A few points on the morphology of the Trematodes may now be discussed. Odhner discovered a large blood fluke *Aporocotyle* from the gull and indicated its importance in the absence of suckers and similarly *Sanguinicola* was obtained from fish and this also was devoid of suckers. In such cases it was an adaptation to the mode of life of these flukes which were related to *Aporocotyle*. Recently, I recorded a hermaphroditic blood-fluke, *Tremarhynchus* (Thapar 1933b) from an Indian tortoise with the characteristic disposition of the ovary between the testes and showed how it links the genera *Hapalotrema* and *Hapalorhynchus*. The presence of the cirrus and its position along with that of the seminal vesicle, both in front of the testes in this case, is unique in the sub-family Hapalotreminae. Sinha (1934) discovered *Gomtiotrema* with multiple testes like Spirorchinae, but with a ventral sucker like Hapalotreminae. All this gives us an indication about the phylogeny of the genera included under the family Spirorchidae. Other forms discovered by him strengthen the view expressed.

With the discovery of a curious Avian trematode, *Balfouriella*, Leiper demonstrated the presence of a communication between the intestine and the excretory bladder. Other forms were subsequently discovered and involved a revision of the belief that the intestine in the trematodes ends blindly. The presence of this connection between the two systems was interpreted by Odhner

to be the formation of a secondary anus. Other forms like *Diploproctodaeum*, *Bianium* and *Acanthochasmus diploporus*, indicate independent openings of the intestinal caeca at the posterior end besides the excretory pore. It is interesting to note that these forms with posterior intestinal openings either directly or through the excretory vesicle, belong to different families of trematodes that are not related to each other. Again, the discovery of *Gomtia* from Lucknow fishes (Thapar 1930b) further adds to the illustrations of the method by which accessory intermediate hosts may come to be interpolated in the life history of a parasite. The relatives of this form are found as adults in the fish-eating birds and mammals, the fish serving as a second intermediary in which they encyst. Its occurrence in fish as adults is quite interesting.

Amongst the other forms described from Lucknow, the genus *Cotylogonoporum* (Thapar and Dayal 1934) from a fish appears to be of great interest as besides giving a clue for the revision of the family Allocreadiidae, it possessed a feature in which it resembles members of the family Heterophyidae—*i.e.* the possession of a genital sucker. It gives us hope for further research which may show a possible relationship between the two families of Allocreadiidae and Heterophyidae through the new family Sphaerostomatidae. (Thapar and Dayal, 1934.)

A study of the snails for the infective stages of Trematode parasites has been carried out successfully and has yielded fruitful results. It has been possible to recognise the following representative types of cercariae from fresh water snails :—

1. Monostome cercariae.

2. Xiphidiocercariae with stylets.

3. Furcocercariae (*a*) Schistosomatidae.
(*b*) Strigeidae.

4. Echinostome cercariae.

5. Amphistome cercariae.

6. Cystophorous cercariae.

7. Flavopunctate cercariae, and

8. Syringicaudate cercariae.

Although most of these can be recognised from the superficial characters, the main difference lies in the nature of the excretory system which has been regarded as a deep-seated and constant feature in all the known families of trematodes. This system is the first to be established in the larva and definite patterns in the course of flame-cell formation could be recognised, particularly in determining the relationships of the different groups of cercariae. Sewell's researches (1922) in India deserve special mention as being of outstanding merit. In 1930 he also discussed the course of evolution of the excretory system in certain groups of Furcocercariae. The starting point is taken of a case with *four* flame cells—two opening into the anterior and two into the posterior collecting duct on either side. Of these four flame cells, *three* are in the body and *one* in the tail. On the basis of this feature he regards the Schistosome cercariae to be prim ive amongst the Apharyngeal brevifurcate distomes; in the course of evolution the individual flame cell is supposed to have divided successively with the result that the anterior daughter-cell of the tail flame-cell migrates into the body and is added on to the body flame cells. In the Pharyngeal longifurcate group (Strigeid cercariae) there is no primitive representative but we find two groups—

the *Strigea* series, with cross connections between the main excretory tubes of the two sides and the *Proalaria* series, without such connections. A third group contains forms with 3, 4, or 5 basic groups of *two* flame-cells each and they are shown to be formed by the division of the primitive 4-flame cell system. Owing to the absence of a cross connection between the main excretory ducts they appear to possess relationship with the *Proalaria* series. The order of division is different from that of the longifurcate distomes and indicates a polyphyletic origin of the furcocercous cercariae.

Much attention has been paid in recent years to the nature of certain glands in the head region of the cercariae and they are variously regarded as salivary, cephalic, digestive, mucous, mucin, salivary-mucin, periacetabular and secretory. The majority of investigators call them "*penetration glands*" and regard them to be of two kinds in the brevifurcate larvae—*oxyphilic* (with coarse granules) and *basophilic* (with fine granules). They have been differentiated by intra-vitam stains with neutral red and it has been suggested that they are complemental in their action during penetration of the cercariae into the host. This needs confirmation. Best's alum carmine has been used in certain cases to identify "glycogen" in some of the gland cells of cercariae, but the results have been disappointing. *It may be pointed out that this stain, although successful with Vertebrate tissues, has given indefinite and unreliable results in the case af invertebrate tissues and is, therefore, highly unsuitable and inconclusive.*

The formation of pearls in the fresh water mussel is said to be due to larval worms. It was pointed out by Jameson that the presence of the larval trematode induces the formation of pearls. Later, Hornell and Herdman

advanced the view that the agent in the formation of the pearls in the Ceylon pearl oysters is a larval tapeworm (*Tetrarhynchus*) and it was encouraged to induce their growth on oyster-beds for increased pearl yield. Careful work on this subject may result in showing the utility of the helminthic infections of animals.

The study of the parasites of wild animals is of immense service. Leuckart (*vide Lect. II, p. 24*) obtained the clue to the life-history of the guineaworm from that of fish roundworm, *Cucullanus*. Further, wild animals carry parasites that are transmissible to domestic animals and man. Not only this, wild animals act as intermediate hosts for human and stock worms. Fish heavily parasitised with young broad tapeworms and encysted liver fluke of dog and of man serve as carriers of the parasites, and if the fish parasites had not been studied, the connection of the infective stage of human parasites would have been difficult to obtain. All this shows the value of the study of parasites of wild animals as an aid to the elucidation of the connected problems in man and domestic animals.

It may be mentioned here that the helminth fauna of vertebrates has been poorly investigated in India and offers a great field; not only amongst the wild animals, but also amongst the domesticated animals. There are very meagre records of the helminthic infections of the domestic animals in India. Amphistomes, for instance, are a great menace and are constantly threatening stock. The life of the animals is becoming difficult on account of this pest and its degenerating effects are apparent by their poorer yield of milk, meat and other animal products. The life-histories of most of these helminths are unknown and need many years of patient work. A little statistical work done by me relating to the incidence of helmin-

thiasis in the slaughter houses at Lucknow (Thapar, unpublished results) indicated a wide scope for work, but this could not be conducted for want of suitable assistance and funds. A scheme was, therefore, submitted to the Imperial Council of Agricultural Research for financial aid. It is gratifying to note that the scheme has been favourably considered and as soon as the funds are released the work will be started.

In India there are a large number of indigenous drugs that may prove effective in the removal of the helminth parasites from the body of the host. There is thus a great field of useful research for those interested in the investigation of the action of these drugs as anthelmintics. The common wild ferns in our hills may be tested for their anthelmintic properties in their natural form.

There is also a good deal of experimental work to be conducted on the effects of the dietary supplement by vitamins and yeasts, etc., on the incidence of parasitism and the immunity problems, as also the effects of hyperparasitism on immunity to helminthic infections. Work on similar lines has already been started in America and Japan and has yielded promising results. The names of Ackert in America and Nagoya and Hiraishi in Japan may be mentioned in this connection.

These are a few of the lines along which profitable work could be carried out in India to put this country on a par with other countries of the world in helminthological research, and it is hoped that the Government bodies or private benefactors will come forward to encourage research in this useful field.

Perhaps it would be appropriate to mention here the desirability of establishing co-operation between the

zoologists and the veterinarians. Such co-operation is likely to yield fruitful results. Past experience of co-operation between zoologists and physicians and sanitarians in the matter of human parasites has brought to light facts that promise of their complete eradication and similar results may be expected here as well. In fact, remarkable results of this co-operation are already becoming apparent when we know how zoologists have been able to show the veterinarians that the cause of the skin disease commonly known as "Cascado" in the Dutch East Indies is not "mange mites" as was originally supposed, but it is due to a nematode worm of the genus *Stephanofilaria* (Ihle, 1933 and Dikmans, 1934). Similar revelations of *Schistosoma spindalis* in India as the cause of nasal granuloma in cattle indicate the magnitude of work based on such a co-operation and strengthen my belief, already expressed in an earlier lecture, of having a trained zoologist in charge of such investigations in the veterinary department of a Province.

We may mention here a recommendation of the Royal Commission on Agriculture in India, where they have emphasised the need of co-operation between the Universities and the Agriculture and Veterinary Research departments. The assistance that the Universities have already given and are giving in different investigations is well known. Owing to the unsuitability of all-India research stations, the Royal Commission have also suggested the establishment of research sub-stations at suitable localities in the Provinces. In this connection, I would venture to suggest the establishment of such sub-stations at the Universities. This is likely to bring better results and greater co-operation between the Universities and the Government departments and would be in the interest of both the Government and the Universities. The usefulness of such an institution is self-evident. It

would, besides doing research on Animal Parasitology in its bearing on agriculture, veterinary science, public health, etc., be a useful agency in the training of students in this new line of work. Similar research centres are attached to the Universities in the West. One of them, the Institute of Agricultural Parasitology at the London School of Hygiene and Tropical Medicine, is attached to the University of London, and is financed by the Ministry of Agriculture and Fisheries. This is one of the largest and the best equipped laboratories, to which an agricultural farm is attached, and it is carrying on researches of far-reaching importance. At Cambridge, too, the Molteno Institute of Research in Parasitology is established for work on similar lines. There are similar research centres in the Universities of France, Germany, Switzerland, Palestine, Russia, Egypt, America and Japan. The Government of Burma have recently provided a Helminthological Institute at the University of Rangoon for this useful line of research and it would not be too much to ask for the establishment of at least one such Institute in connection with a University in India, particularly when we consider the progress in research made in other countries. The call for research in this line is urgent and in view of the adoption of the recommendations of the Royal Commission on Agriculture, I would venture to suggest that the adoption of the proposal would greatly extend the benefits of Agricultural Research over a wider area than is possible at present.

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